SUSTAINABLE SEMI-INTENSIVE POLYCULTURE OF SEABREAM AND SOLE IN EARTHEN PONDS

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INTRODUCTION

Earthen ponds are the main production system for seabass and seabream in Portugal and in Southern Spain, in particular in Cádiz province. Different farms use various levels of stocking densities and pond sizes, but in general these are semi-intensive systems covering large areas with ponds ranging from one to several hectares and production levels from 0.5 to 6 Kg/m^3 (mostly below 2 kg/m^3) at the end of the production cycle.

Although seabass and seabream are traditionally the target species produced in such ponds, there is commonly natural recruitment of wild larvae of other fish species, including Senegalese sole. Previous attempts at ongrowing sole in ponds with seabass and seabream as added value gave varied results in terms of number of individuals recovered, but sole growth rates were promising. Polyculture of seabass and seabream is already an established practice, with proportions of 4:1 normally used. In seabass dominated ponds seabream is used to control growth of macroalgae and to clean the ponds. When seabream production dominates, the carnivorous nature of seabass is used to control populations of smaller fish which enter the ponds naturally and might compete for feed. Polyculture of species from different trophic levels has also been considered an efficient and environmentally sound strategy to minimise the impacts of aquaculture systems, since an important fraction of dissolved nutrients and organic matter is recycled within the pond (Buschmann *et al.* 1996, Sorgeloos 2001, World Bank 2006).

Fig. 1. Corte das Freiras semi-intensive fish farm (Gafanha da Nazaré, Aveiro, Portugal) (Photo: P. Raux).

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The improvement of diet formulations (e.g., finding an optimal protein/energy ratio) also contributes to the increase of production and the reduction of environmental impacts of semi-intensive aquaculture (World Bank 2006). The proportion of nutrients utilized for fish growth can be maximized, for example by selecting very digestible ingredients that facilitate nutrient assimilation and promote the improvement of FCRs (Feed Conversion Ratios), and at the same time reduce the amount of waste and nutrient output from fish farms. Eco-friendly feeds, in which fishmeal protein is replaced by a vegetable protein sources, may also contribute to the reduction of aquaculture's ecological footprint by reducing the pressure on natural fisheries resources (Kaushik *et al.* 2004).

Despite positive effects including environmental protection and restoration in areas of ecological interest and new opportunities for employment and development of rural and coastal areas, semi-intensive aquaculture systems also have some drawbacks. The difficulties faced by this type of aquaculture are largely related to its high production costs (mainly high labour, energy and land costs) that compromise its economic sustainability due to the lower productivity of these systems compared to intensive (cage) systems. Factors contributing to the low profitability of semi-intensive aquaculture systems are its reliance on natural resources (for example, water quality) and technical limitations since little controlled research effort has been done so far to improve such systems, which rely largely on traditional practices and empirical improvements developed by farmers. We believe that economic sustainability of these semi-intensive systems depends on product differentiation and optimization of production.

In order to demonstrate the feasibility of productivity enhancement under sound environmental conditions, a case study was designed in the framework of the SEACASE project (www.seacase.org). The objectives of the case study included testing different improved production protocols in the earthen ponds which are presently used to ongrowing Gilthead seabream and European seabass in the South of Portugal and Spain. Production was enhanced through different approaches:

Fig. 2. Earthen ponds used for semi-intensive trials at IPIMAR´s EPPO research facility, located in Ria Formosa, near Olhão (Portugal) (Photo: A. Ramalho).

1) increasing revenue per ton of feed supplied to the system, while reducing its environmental impact, through polyculture of species with different feeding niches: seabream (feed, macroalgae), and Senegalese sole (benthos, feed);

2) Increasing production per hectare while maintaining sound environmental conditions;

3) Launching a basis for increased added value to the production through a certification processes;

DETAILS OF THE CASE STUDY

A controlled trial was performed at IPIMAR´s aquaculture research station (EPPO, Olhão, Portugal), using six ponds each with 385 m^2 bottom area and 765 m^3 of volume.. Senegalese sole (*Solea senegalensis*) and gilthead seabream (*Sparus aurata*) juveniles were stocked with initial average weights of 2.05 and 24.2g in April and May 2008, respectively. Replicates of three ongrowing conditions were tested: a control at low density (Low) using the standard fish stock density at commonly used earthen pond , i.e.,1.5 Kg / m^3 at harvest in the first year, higher density (High) aiming 3.0 Kg / m^3 at first year of harvest and eco-friendly (Eco) using a special environmentally friend feed formulation with standard density. Fish belonging to Ctrl and High groups were fed a commercial seabream feed. The eco-friendly and commercial diets were produced under identical industrial extrusion conditions (Sorgal SA, Ovar, Portugal), and were isoproteic (54% DM), isolipidic (17% DM) and isoenergetic (23 kJ/g DM). The commercial feed had a total of 32% as marine-derived protein sources, and fish oil was used as the main fat source. The Eco diet was formulated to replace 60% of marine-derived proteins by alternative sources (haemoglobin, soy, peas, wheat and corn gluten) and 30% of fish oil by soybean oil. From April 2008 to February 2009, all fish were fed commercial feed pellets, and from March 2009 to July 2009, Eco feed was given to the two tanks of the Eco group. The daily ration was based on a feeding table and adjusted according to temperature and fish apparent appetite. Daily ration was divided into three meals supplied by automatic feeders. Samples were taken at regular intervals for evaluation of water quality and benthic populations. Fish proximate composition was determined at the end of the trial.

BENTHOS MONITORING

With exception of earthen ponds with higher fish stocking density (High), that were almost devoid of benthic organism, communities were largely dominated by annelids, mostly polychaets (Fig. 3), and molusca.

The low density and the eco-friendly treatments show a considerably variation in benthic organisms abundance and composition between tanks, even in the same treatment (Fig. 3). These results may be at least partially explained by differences in fish final densities in the tanks.

Low density (Low) and eco-friendly (Eco) treatments showed a considerably variation between tanks, even within the same treatment (Fig. 3). These differences may be partially explained by variations in final fish species ratios in the tanks. The almost complete absence of benthic organisms in the high density tanks, may be due to higher grazing exerted by the fish which exceeded the benthic production capacity in the tanks.

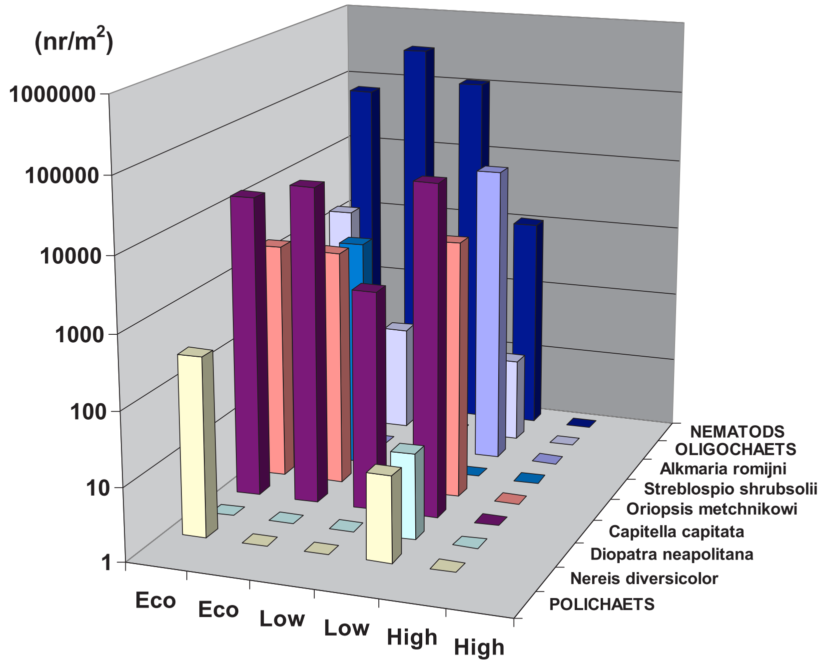

Fig. 3. Abundance of Annelids in the sediment of polyculture earthen ponds with seabream and sole, at the end of the production cycle (June 2009), in each earthen pond.

GROWTH AND PRODUCTION

No significant differences in seabream final weight were observed between treatments, with final mean weights, for each pond, ranging from 305 to 364 g. At the end of the trial production of seabream fed with commercial feed in standard density ponds (Low) was slightly higher (24 Ton/ha) compared with fish were fed with eco-feed (22 Ton/ha), but this difference is considered of little significance. Doubling the standard stocking density used in Portugal (High) lead to an increase in the final production of seabream (54 Ton/ha).

Sole final production (Fig. 4) was highly variable between tanks and among treatments which seemed to be related to bottom conditions namely whether there were anoxic layers or not. Ponds with the best bottom condition at the end of the trial presented the best results. At higher fish (seabream and sole) stocking densities (High), sole production was low due to poor growth. Considering that food conversion ratios were quite high (above 2.5 in all tanks), which indicated that seabream were fed to excess, it is quite probable that dry feed was available but not eaten by sole and that excess of uneaten feed lead to deterioration of bottom conditions and to drastic decrease of benthos (Fig. 3). Furthermore sole production correlated well with the abundance of benthic organisms at the end of the trials suggesting that sole in earthen ponds mostly eat benthic organisms. Interestingly, sole production correlated very well with abundance of the ragworm *Nereis diversicolor* (Fig. 3), a species known to be highly appreciated by sole. This suggests that eventually the abundance of this species may be used as an indicator of sole biomass and/or food availability for sole, for management of earthen ponds.

All these results support the idea that sole farming in earthen ponds is viable providing good bottom conditions are maintained with sufficient natural food which is only possible at low fish stocking densities either in polyculture or monoculture.

Sole final production (Fig. 4) was highly variable between tanks, both between and within treatments, which seems to be largely related to pond bottom conditions, namely whether there are anoxic layers in the bottom. In fact was observed that ponds where sediment showed the best condition at the end of the trial were the ones that presented the best results with good recovery rates of sole (up to 99% recovery, in two ponds). In addition, at higher seabream / sole stocking densities, sole production was low due to poor growth. This confirms the idea that sole farming in earthen ponds is viable when good bottom conditions provided and sufficient food is available.

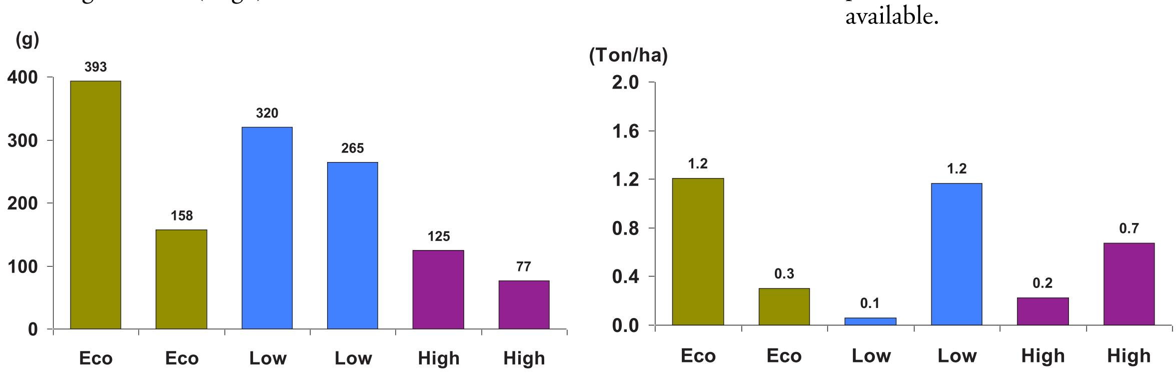

Fig. 4. Sole final average weight (g) and production (ton/ha) in the earthen ponds with seabream.

Furthermore, sole production also correlated well with the abundance of benthic organisms at the end of the trials (Fig. 3), suggesting that sole in earthen ponds eat mostly benthic organisms. Considering that the feed conversion ratios were quite high in the IPIMAR trial (above 2.5 in all tanks), it can be assumed that seabream were fed in excess, and therefore dry feed was available, but not eaten, by sole. Again this supports the idea that sole farming in earthen ponds is only viable at low density, probably both in polyculture and monoculture. This is in line with poor results in attempts at farming sole in monoculture in earthen ponds by several Portuguese and Spanish farms.

Interestingly, sole production correlated very well with abundance of the ragworm *Nereis diversicolor* (Fig. 3), a species known to be highly appreciated by sole. This suggests that eventually the abundance of this species may be used as an indicator of sole biomass and/or food availability for sole, in earthen ponds management.

A forecast of semi-intensive production in polyculture of seabream and sole was also estimated (Fig. 5), based on the results of the present trial. This exercise shows that sole production can contribute important added value to seabream production in semi-intensive earthen ponds, provided that low densities are used and pond bottom status is well managed.

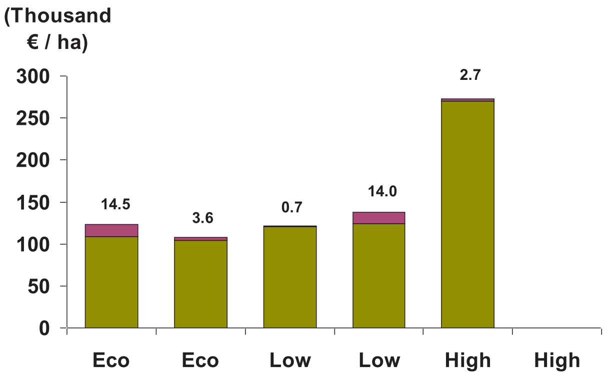

Fig. 5 Forecast of Production value of seabream and sole in polyculture at the end of the production cycle (July 2009), in each earthen pond. Sale prices for seabream and sole were assumed to be 5 and 12 Euro/Kg respectively. Numbers on top of bars referred to forecast sole production value alone

WATER QUALITY MONITORING

Concerning water quality the physical and biological parameters of the water in earthen ponds seemed more dependent on temperature (seasonal effect) than on farming protocols. However, higher fish densities tended to increase the amount of suspended particulate matter (SPM) in effluent waters, probably as a result of fish activity (fish faeces, uneaten feed or sediment re-suspension due to fish bioturbation). Fish density also seemed to affect the chemical composition of effluent waters, since organic nitrogen compounds (dissolved organic nitrogen and urea) were higher in the effluent waters of high density ponds, most likely due to fish excretion. Suspended particulate matter values reflected mainly the effect of fish activity rather than feed quality, since no significant differences were found between the ponds supplied with commercial and eco-feeds. Despite the limited duration of the feed trial, the use of eco-feeds seemed to reduce the amount of dissolved organic phosphorus released into the environment, minimising the impact of semi-intensive earth pond aquaculture. In any case, water parameters of effluent waters in all treatments were within the normal ranges found in coastal lagoon systems (Falcão and Vale, 2003), indicating that the farming protocols were environmentally sustainable.

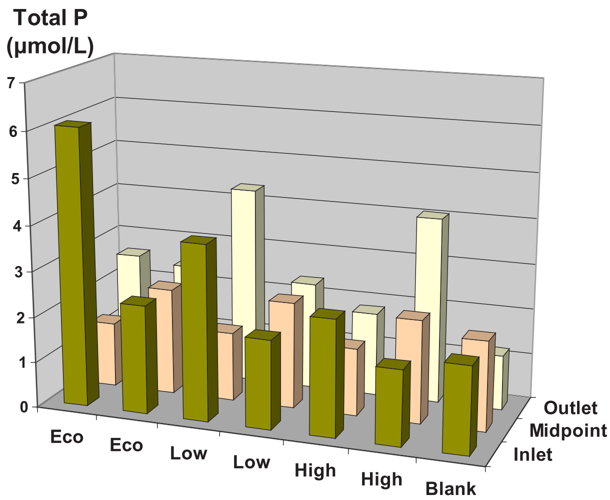

Fig. 6. Total phosphorus measured in inlet, midpoint and outlet, of the earthen ponds where seabream and sole were farmed in polyculture, close to the end of the production cycle (May 2009).

QUALITY OF THE FINAL PRODUCT

No major differences in gilthead seabream tissue composition at the end of the production cycle could be observed between treatments. Analysed parameters were: muscle amino acid composition, muscle fatty acid composition, whole body composition and body fractions yield. In particular amino acid composition, whole body composition and body fractions yield, were very stable among treatments, despite small differences in fish body weight at sampling.

CONCLUSIONS

Altogether, these results support the idea that sole farming in polyculture with seabream in earthen ponds is only viable at low densities, when sufficient natural food is left behind for sole. Higher seabream densities (up to 3 Kg/m^3 at harvest) lead to macrobenthos depletion, explaining thereby the poor results with sole rearing at such densities, but do not seem to have a negative impact on water effluent quality. They also show that recovery of stocked sole is quite variable. It depends on maintaining good pond bottom conditions, namely preventing the creation of anoxic layers in the bottom.

Analysis of water quality suggested that physical and biological parameters of water in the semi-intensive earthen ponds were more dependent on seasonal effects (temperature) than on farming protocols. Water parameters of effluent waters were within normal ranges for coastal lagoon systems, suggesting that the used farming protocols were environmentally sustainable.

Feeds with low incorporation levels of fish meal, and consequently lower release of soluble phosphorus are considered more environmentally friendly when compared to common commercial feeds, and can be used without adverse effects on production or on flesh quality.

The present study shows that semi-intensive polyculture of fish in earthen ponds can be an environmentally sustainable activity producing high quality fish. This may be the basis for a certification process that ensures added value to this type of production.

Acknowledgements

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Fig. 7. Portion-size gilthead seabream and Senegalese sole produced in the polyculture trial in semi-intensive Earthen ponds. (Photos: A. Ramalho)

REFERENCES

Buschmann AH, López DA, Medina A (1996) A Review of the Environmental Effects and Alternative Production Strategies of Marine Aquaculture in Chile. *Aquacultural Engineering* 15, 397-421

Falcão M and Vale C (2003) Nutrient Dynamics in a Coastal Lagoon (Ria Formosa, Portugal): The Importance of Exchanges Lagoon Water - Sea Water on the Biologic Productivity. *Ciencias Marinas* 29, 425-433

Kaushik SJ, Covés D, Dutto G, Blanc D (2004) Almost total replacement of fish meal by plant protein sources in the diet of a marine teleost, the European seabass, *Dicentrarchus labrax*. *Aquaculture* 230, 391-404

Sorgeloos, P. (2001) Technologies for sustainable aquaculture development, Plenary Lecture II. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 23-28. NACA, Bangkok and FAO, Rome. http://www.fao.org/docrep/003/ab412e/ab412e12.htm

World Bank (2006) Aquaculture: Changing the Face of the Waters Meeting the Promise and Challenge of Sustainable Aquaculture. The World Bank, Washington, 138 pp